

A review of the history, geology and age of Burmese amber (Burmite)

V.V. ZHERIKHIN

Arthropod Laboratory, Paleontological Institute, Russian Academy of Sciences, Profsoyuznaya Str. 123, Moscow 117647, Russia

A.J. ROSS

Department of Palaeontology, The Natural History Museum, Cromwell Road, London SW7 5BD, UK

SYNOPSIS. An overview of the present state of knowledge of Burmese amber is given based on an exhaustive literature search. Early Chinese literature suggests Burmese amber has been known since the 1st century AD and was later traded from northern Burma to Yunnan Province. Amber has been recorded from five regions in Burma (Myanmar): the Hukawng Valley, Shwebo District, Thayetmo District, Pakokku District and Pegu District, but only Burmite from the Hukawng Valley in northern Burma has been commercially mined. The first visit by a westerner to the amber mines in the Hukawng Valley was by Captain Hannay in 1836. Subsequent visits by members of the Geological Survey of India showed that the amber-bearing deposits are of Middle Eocene age and consist of shales and sandstones with subordinate limestone and conglomerate horizons. The archaic insects in Burmite and the presence of derived clasts in the amber-bearing sediments suggest that the amber has been reworked and is probably of Upper Cretaceous age.

INTRODUCTION

Amber is fossilized plant resin. There are many different types which may contain the remains of organisms that were trapped by liquid resin. They provide much palaeontological information, particularly about small terrestrial animals which are rarely preserved in sediments. The inclusions in amber, such as insects, often show very delicate morphological details which can rarely, or never, be seen on other kinds of fossils. For a long time, Baltic amber was the only fossil resin extensively studied palaeontologically while records of inclusions in other resins were scarce and mostly anecdotal. The situation changed during the last decades when systematic studies of organic inclusions in various fossil resins were developed (see Poinar, 1992 for a review). However, many kinds of amber are still poorly investigated.

Burmese amber, or Burmite is one of the most mysterious varieties of fossil resins in the world. Though known for nearly 2000 years in southeastern Asia and for four centuries in Europe, it is poorly investigated scientifically, first of all because of the location of its deposits in a remote area of Upper Burma which was never easy to reach by a traveller. In this area there were the so-called 'unadministrated territories' in colonial times and later, in independent Burma (now Myanmar), this area, situated between the 'Golden Triangle' and the politically unstable Nagas region of India, remains controlled rather by the local clans and insurrectionists than by the central government in Rangoon. Few geologists have visited this area, each for a short time only, and the published data on the amber occurrences are scarce. A comprehensive review of the literature has been undertaken and this paper outlines the present state of knowledge of Burmese amber.

THE HISTORY OF BURMITE

0–1800 AD

The most thorough account of the early history of trade in Burmese amber is by Laufer (1906), summarized by Penzer (1922) and

Fraquet (1987). Laufer published translations of passages referring to amber from ancient Chinese literature. He considers that the Chinese became familiar with Burmese amber in the 1st century AD and that trade in amber between Burma and Yunnan Province became established soon after. This was based on the *Hou Han shu* (Annals of the Later Han Dynasty, 205–265 AD), which mentioned amber in Ai lao, the ancient Shan kingdom in Yunnan which formed in the 1st century AD. Laufer indicated that mentions of amber from Yunnan in the Chinese literature became more frequent during the following centuries. The production of amber in Yung ch'ang in Yunnan is recorded in the *Kuang ya* (a dictionary from 227–240 AD), the *Po wu chi* (Records of remarkable objects, from 232–300 AD) and the *Pieh lu* (a medical book of uncertain age, referred to in a later work of 452–536 AD). Laufer (1906) however, considered that the amber from Yunnan originally came from Burma as Yung ch'ang is only 180 km from the amber mining area in Burma. Pumpelly (1867) also recorded amber from Yungchang in Yunnan, and also from other localities in Shansi, Shensi, Szchuen, and Kwangtung provinces; so it appears that China does have its own amber deposits. Laufer (1906), however, was sceptical about reports of native Chinese amber and considered that they may refer instead to other resins. It should be noted that European amber was being imported into China at least as early as the 18th century and that the Chinese had the ability to fake amber from early times (Laufer, 1906). The very large piece of Burmese amber figured by Grimaldi (1996, p. 41) and Ross (1998, p. 14, fig. 33) (Natural History Museum (London), Mineralogy Department, specimen no. 1940,37) was originally purchased in Guangzhou (Canton), China in 1860. D. Grimaldi and A. Shedrinsky (pers. comm.) have confirmed that it is Burmese amber using pyrolysis-gas chromatography. An analysis of the old Chinese literature together with archaeological data may elucidate the relative importance of Burmese amber in ancient and medieval China but at present this question seems to be unclear. It appears that there are no reviews of records of amber from old Burmese written sources which would be expected. It may be stated that Burmese amber was known in China for a very long time, perhaps since the 1st century AD, and that the export of amber from Burma to Yunnan continued for many centuries. According to Laufer (1906), the first European who mentioned Burmese amber was the Portuguese Jesuit Father Alvarez

Semedo who visited China in 1613. In the English edition of his book on China, published in 1655, he wrote that the amber from Yunnan is 'digged out of mines, and some times in great pieces: it is redder than our Amber, but not so cleane.' In 1738 Du Halde also mentioned a red amber from Yunnan (Laufer, 1906). All these early records were quite brief and contained little information about the amber itself.

1800–1885

The first short description of Burmese amber was published by Brewster (1835) who investigated one large piece and pointed out that 'its general aspect and physical properties seem to differ considerably from the ordinary specimens of amber'. In particular, the presence of fissures filled by calcite was noted for the first time.

Two years later Pemberton (1837) published an extract from the journal of Captain S.F. Hannay who was the first European to visit the amber mines in 1836 and described them briefly. Hannay mentioned two amber sites in the Hukong (more correctly, Hukawng) Valley, one called 'Payen-toung or amber-mine hill' where the amber is mined and another on the east side of the valley called Kotah-bhum and noted that the latter site 'is considered sacred by the Singphos, who will not allow the amber to be taken away, although it is of an inferior description' (Pemberton, 1837: 270). Hannay wrote that the amber is the only subject of barter with the Chinese in this area and its price varies considerably in relation to its quality. He also described the amber mines visited personally by himself as pits of 2–4.5 m in depth, dug in a reddish and yellow clay with a smell of coal tar. The only instruments used by miners were 'a bambu sharpened at one end, and a small wooden shovel' (Pemberton, 1837: 274), and Hannay pointed out that a low production of amber is the consequence of these primitive techniques. He goes on to say 'the deeper the pits are dug, the finer the amber; and that that kind which is of bright pale yellow, is only got at the depth of forty feet under ground.' Hannay observed also a number of abandoned pits. Pemberton's (1837) publication is accompanied with a map showing Hannay's route.

Ten years later another description of the amber mines was published in a collection of posthumous papers by Griffith (1847) who accompanied Captain Hannay to the same area in 1837, one year after Hannay's first visit. Chapter IV (Griffith, 1847: 60–81) gives a detailed account of their 'Journey from Upper Assam towards Hookhoom, Ava, and Rangoon' and all the wildlife encountered. He refers to the Hookhoom Valley rather than Hukong and figures a sketch of the valley. Griffith (1847: 77) described the amber mines 'situated on a range of low hills, perhaps 150 ft [46 m] above the plain of Meinkhoon, from which they bear S.W.' His observations are similar to those of Hannay except Griffith adds more detail. Griffith (1847: 77) describes the pits as 'square, about four feet [1.2 m] in diameter, and of very variable depth; steps, or rather holes are cut in two of the faces of the square by which the workmen ascend and descend.' Griffith does not mention a restricted sacred area. He supplemented Hannay's observations by the first short description of the rock sequence; he wrote that 'The soil throughout the upper portion, and indeed for a depth of 15 to 20 feet [4.6–6 m], is red and clayish, and appear to inclose but small pieces of lignite; the remainder consists of greyish slate clay increasing in density as the pits do in depth: in this occur strata of lignite very imperfectly formed, which gives the grey mineral a slaty fracture, and among this the amber is found' (Griffith, 1847: 78). The deepest pit seen by Griffith was 'about 40 feet [12 m], and the workmen had then come to water.' The amber he saw 'occurred as very small irregular deposits, and in no great abundance'. He believed that the miners 'have no index to favourable spots, but having once found a good pit they of course dig

as many as possible as near and close together as they can.' The passage concerning the amber mines was reproduced later by Noetling (1893a).

In 1852 and 1853 Piddington described under the name of Hircine a dark brown fossil resin which Penzer (1922) indicates came from the Pakokku District. This was the first information about the occurrence of a fossil resin in Burma outside the Hukawng valley. In the Mineralogy Department of The Natural History Museum (London), there is a large rounded piece (no. 54956) which is labelled as coming from Pegu in the Pegu District. It was transferred from the India Museum in 1879. Amber from Pegu has not (as far as the authors are aware) been mentioned in published literature. It is possible that the label is incorrect and that it came from the Hukawng Valley (see below).

Watt (1908: 64) indicates that in 1876 there were only a few amber workers in Upper Burma. Ball (1881: 57–58) summarized observations made by Hannay and Griffith and also mentioned unpublished notes by Bayfield about his visit to the amber mines area. He believed that the mines 'in the valley of the Hukung or Hookoon . . . have been worked with varying success for a very long period and have, it is believed, produced a large quantity of amber.' Mason & Theobald (1882: 15) say very little about Burmese amber. They mention Griffith's expedition and publish a quote by Anderson – 'the amber most valued at Momien is perfectly clear, and of the colour of very dark sherry, and is sold by its weight.' Up until 1885 the main trade route would still have been from Upper Burma to Yunnan in China.

1885–1947

In 1885 the British deposed the Alaungpaya dynasty and Burma became an annex of India. The commercial interest in Burmese amber increased and the market displaced from China to Mandalay and Rangoon in Burma.

The Geological Survey of India sent Dr. Fritz Noetling to investigate the amber mining area in northern Burma. The results were published in several papers containing the first detailed description of the amber occurrences (Noetling, 1892, 1893a) and summarized briefly in the annual report of the survey (King, 1893). Some amber samples taken by Noetling were examined by Otto Helm, who assigned Burmese amber from the Hukawng Valley to a new mineral species, called by him Burmite (Helm, 1892, 1893a, 1894, 1902). Noetling (1893a) and Helm (1892) were reprinted as a separate article in Rangoon (Noetling, 1893b, Helm, 1893b), along with a map illustrating the position of the mining area. Noetling (1893a) visited the same part of the Hukawng Valley (he called it Hukong) which was described earlier by Hannay and Griffith (Fig. 1). The mines seen by Noetling were situated south-west of Maingkhwan village (or Maingkwon, called Meinkhwon by Hannay and Meinkhoon by Griffith) at a low hill range, 8 km long, trending north-south which he called Nangotaimaw. The position of the range was fixed at Latitude 26° 15' N, Longitude 96° 30' E; (Maingkhwan lies at 26° 20' N, 96° 36' E). Like Hannay and Griffiths, Noetling could see only quite a small quantity of amber during his visit. He was surprised because at that time the amber trade in Mandalay was already well developed. However, Noetling was informed by Chinese traders that the main mines are at the southern end of the range near Lalawng (Lalaung) village; he had no possibility to prove this record but considered this information as very probable. Noetling (1893a: 35) found that the Nangotaimaw range consists 'of a blue, more or less hard clay, dipping at a high angle (88°) towards west.' He failed to discover any fossils in the clay but assigned it tentatively to the Lower Miocene because of a great similarity with the blue

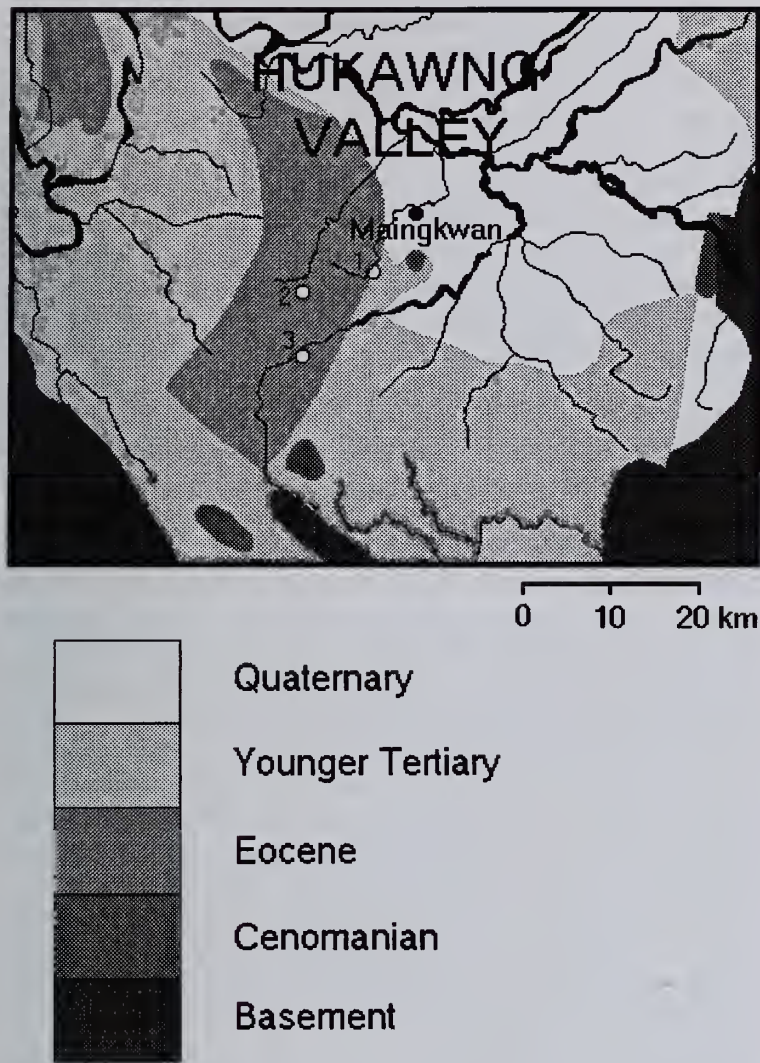


Fig. 1 Map of the amber mining area in the Hukawng Valley, northern Myanmar showing the general geology, the main town of Maingkwan (black dot) and the amber mines (white dots) for which co-ordinates are known – 1 Khanjamaw, 2 Lajamaw and 3 Ladummaw.

clays of the Chindwin Group. It should be noted, however, that Noetling found a pebble containing an ammonite but could not established its origin; Griesbach (1892) supposed that it was of Cretaceous age and probably originated from the conglomerates of the amber-bearing formation. Noetling (1893a) found that the different colour of the upper part of the clay deposits, as noted by Griffith (1847), is the result of weathering, and that the amber from this weathered zone is dull and brittle and had a thick oxidized crust. According to Noetling’s (1892, 1893a) observations, the amber is distributed unevenly and forms pockets in the clay, but the position of the pockets cannot be determined before digging. He also noted that the pieces of amber usually have a pebble-like shape and supposed that the amber was transported by water and ‘have undergone a certain amount of wear and tear before they were deposited at their present resting-place’. The techniques of amber digging described by Noetling was the same as observed by Hannay and Griffith. He was rather sceptical about the economic potential of the amber; in his view Burmese amber could not compete with Baltic amber in the world market because of its ‘colour inferior to that of [Baltic] amber’ and especially because of the presence of fissures filled with calcite. Moreover, at this time the imported Baltic amber already began to replace Burmese amber even in Mandalay where it was known as ‘Indian’ amber and was even cheaper than Burmese amber. Noetling (1893a) noted the presence of insect and wood inclusions in Burmese amber but he did not indicate whether they

were found in the samples collected directly in the Hukawng valley or seen in Mandalay.

Noetling (1893a) mentioned two more areas, Mantha in the Shwebo District and Yenangyat in the Pakokku District, where some pieces of an amber-like resin were discovered. In Mantha small pieces of a brittle resin were found in abundance in a hard coaly clay of Miocene age. According to Noetling, the resin from Mantha resembles Burmite in appearance but he wrote nothing about the single sample from Yenangyat which was seen by him. He also noted ‘numerous Miocene fossils of marine type’ found in Yenangyat together with the resin. Helm (1893a), who examined the resin samples sent by Noetling, gave a short description of their external features but could not establish whether they are identical with Burmite because the quantity of resins was not enough for a chemical investigation. Grimes (1898) also mentioned amber from Yenangyat, which came from thin beds of yellow sandstone within shales. The sandstone beds also contained fragments of fossilized wood. Penzer (1922) indicated that this amber came from Kyun Kyaung stream, 5 km north of Seikkwa (21° 8', 94° 51') and is of Miocene age.

Meyer (1894) in connection with the investigation of archaeological amber materials from Europe published some additional data on the chemistry of Burmite and supposed that this kind of amber may have been exported to Europe in antiquity. Dahms (1901) summarized the data on the chemical composition of Burmite in his review of the chemistry of fossil resins; he noted that the results of analysis of two samples differed considerably and supposed that more than a single mineral species may be present in the Burmese material.

The Geological Survey of India published yearly production figures of Burmese amber from the Myitkyina District for the years 1898–1940 (Holland, 1905; Holland & Fermor, 1910, 1915; Pascoe, 1921, 1925, 1930; Heron, 1935 and Clegg, 1954). The last report was probably disrupted by the 2nd World War. The figures from the reports are summarized in Table 1. It is evident that the annual production of Burmese amber varied considerably during this period, from 36 kg in 1933 up to 10973 kg in 1906 (there are no data for the years 1931

Table 1 The annual production of Burmese amber in the Myitkyina District, Hukawng Valley, Burma, during the years 1898–1940, from the reports of the Geological Survey of India.

Year	Quantity Kg	Year	Quantity Kg
1898	5791	1920	3658
1899	1016	1921	1336
1900	457	1922	183
1901	4928	1923	2433
1902	1524	1924	4536
1903	1880	1925	818
1904	4369	1926	2007
1905	6401	1927	3586
1906	10973	1928	1499
1907	2235	1929	996
1908	2489	1930	107
1909	1575	1931	–
1910	3200	1932	584
1911	711	1933	36
1912	1372	1934	203
1913	508	1935	965
1914	660	1936	1626
1915	584	1937	1981
1916	279	1938	–
1917	3002	1939	304
1918	147	1940	1321
1919	376	Total	82656

Average per year = 1922 kg.

and 1938). The total amber production for the 43 years was 82656 kg, and the average annual production 1922 kg. Each report also contains brief information on the occurrences and physical and chemical properties of Burmese amber, based nearly exclusively on the papers by Noetling and Helm. Holland & Fermor (1915, p. 231) in the report for the years 1909–1913 attributed the decrease in production 'partly to troubles in China with a resultant decreased demand and partly to the rival attractions of rubber plantations and jadeite mining'; there are no attempts to analyse the causes of the fluctuation in amber production in other reports.

In 1916 Cockerell published the first paper containing descriptions of insect inclusions in Burmese amber, sent to him by R.C.J. Swinhoe of Mandalay. Swinhoe, in Cockerell (1916) considered they were of Miocene age. More arthropod inclusions were sent to Cockerell by Swinhoe in the following years and described in series of papers (listed by Ross & York, this volume). Cockerell (1917a, b, c) noticed that the insects were primitive and suggested that the amber was derived from elsewhere and may be much older, even Upper Cretaceous. The materials were presented after description to the British Museum (Natural History) during the years 1919–1921. A brief review of preliminary palaeontomological data was published by Burn (1918) and Cockerell (1920).

In 1920 the amber mines area was visited by Dr M. Stuart as he accompanied the Hukawng Valley Railway Survey. The most important new find was a piece of rock containing the foraminiferan *Nummulites biarritzensis* d'Archiac of Lower Kirthar (Eocene) age, first reported by Fermor (1922). In Stuart's (1923a) full account of his geological observations he wrote that during his visit there was no amber being dug and that he could add nothing to Noetling's observations on the amber mines. He noted that the eastern flank of the hill range, where the amber mines occur, consists of grits and conglomerates belonging to the basal beds of the Tipam Series, which are underlain by the blue amber-bearing clay. Just below the base of the Tipam conglomerates he observed numerous pits dug for flint which occurs as nodules in a thin layer of a chalky limestone. Stuart failed to find this limestone exposed but inspected numerous fragments around the pits and discovered here the single piece containing *Nummulites biarritzensis*. This find led him to conclude that the lowest exposed amber-bearing clay beds were of Eocene age. Cockerell (1922) in his letter to *Nature* agreed with Stuart's conclusion. Cockerell also pointed out that besides the typical red Burmite in the collection sent by Swinhoe there were specimens of a pale yellow resin quite different both in the appearance and in the content of inclusions. In particular, he found in this copal a bee which seems to be identical with the living species *Trigona laeviceps* Smith. Cockerell concluded that the pale resin is very recent, not older than Pleistocene in age. He wrote that Swinhoe was in doubt on the origin of this resin and that it may have come from China. Cockerell (1922) also indicated that the bee described by him under the name *Meliponorytes (?) devicta* Cockerell (1921) is enclosed in this pale resin. Cockerell's letter suggested to Stuart (1923b, 1925) an original hypothesis about the genesis of the Burmese resins. He drew attention to the fact that some modern stingless bees, and in particular *T. laeviceps*, in southeastern Asia use *Dipterocarpus* resin and oil for the construction of their nests, producing a substance called dammar. Stuart hypothesized that the pale resin (copal) containing bee inclusions may be fossil dammar. He suggested that Burmite may have had a similar origin. The presence of many other kinds of insects in both the copal and amber negates this theory. Other published works from about this time (e.g. Coggin Brown, 1924) summarize what was then known of Burmese amber from earlier publications. However, Cotter (1924) records specimens of brown amber found by Clegg near Mibauk, Thayetmo District (19°

27' N, 94° 53' E). These pieces came from stringers of lignite 0.03m thick. Williamson (1932) records three large specimens of Burmese amber, one on display at the Wembley Exhibition of 1924 which belonged to the King of Burma, and two in the possession of Messrs. Liberty.

In 1930 the Hukawng valley was visited by Dr H. L. Chhibber. His observations were summarized in the annual report of the Geological Survey of India (Fermor, 1931) and described in more detail in his book on the mineral resources of Burma (Chhibber, 1934). The latter work is the most detailed description of Burmite occurrences available and is summarized below. Chhibber recommended the preparation of a large scale map of all amber workings and to introduce more advanced techniques of mining to improve the amber mining industry. Chhibber published photos of the amber mines for the first time, two of these were reproduced in Grimaldi (1996).

After 1947

Chhibber's (1934) relatively detailed report on the amber mines of the Hukawng Valley was the last one published. In 1947 Burma gained full independence and little has been published since then. Later publications summarized information from earlier works or discussed the taxonomic position of some previously described insects. One later work (missed by most subsequent authors) that made a significant contribution is Sahni & Sastri (1957) who published observations by Eames on derived limestone clasts from the amber mines which contain the foraminiferan *Orbitolina birmanica* of Cenomanian age. The most recent review of the geology of Burma (Bender, 1983) contains no new data except for some structural observations based on satellite photographs. In 1989 the country was officially re-named Myanmar.

Burmese amber is discussed in nearly every major publication concerning amber (e.g. Schlee & Glockner, 1978; Fraquet, 1987; Poinar, 1992; Grimaldi, 1996; Ross, 1998) but this is based on the previously published literature. Fraquet (1987), Grimaldi (1996) and Ross (1997, 1998) include photographs of specimens of Burmese and Chinese amber. Sometimes it is stated that the amber mines in the Hukawng Valley are now exhausted but there is no information available about their present state (Fraquet, 1987).

GEOLOGY OF THE AMBER DEPOSITS IN MYANMAR

As can be seen from the historical sketch given above, information about the Burmese amber deposits is limited. The summary of the geological data below is based mainly on Chhibber (1934) and Bender (1983).

There are five regions in Myanmar (formerly Burma) where fossil resins have been found: the Hukawng Valley in Myitkyina and Upper Chindwin districts to the north, the Shwebo District in central Myanmar, the Thayetmyo District in the west, the Yenangyat oilfield in Pakokku District, also in the west, and the Pegu District to the south. The samples of fossil resins from Myanmar that have been studied differ in chemical composition and structure (Dahms, 1901; Tschirch & Stock, 1936; Savkevich, 1980) but detailed locality data is absent. The amber from the Hukawng Valley was described under the name of Burmite (Helm, 1892, 1893a) and the resin from the Yenangyat oilfield under the name of Hircine (Piddington, 1852, 1853). It is not known whether Burmite occurs anywhere outside the Hukawng Valley. The Hukawng Valley is probably the only commercial source of amber in Myanmar, and Burmite from there has been

sold in Mandalay and Rangoon since the late 19th century. The specimens with arthropod inclusions kept in Palaeontology Department of The Natural History Museum (London) probably originated from this area.

The Hukawng Basin is a syncline approximately 100 km in diameter (Bender, 1983) (Fig. 1). The sediments dip from 5–20° towards the centre of the basin. Crystalline rocks of the Kumon Ranges form the basement of the basin on the eastern flank, and in the southern and south-western flanks the sediments are bordered by a fault system. Most of the central part of the basin is covered by superficial sediments deposited by the Chindwin River. Three anticlines occur in the centre of the basin, revealed by satellite images, and an additional anticline is revealed in the western flank of the basin. The largest of the central anticlines is where the amber mines occur. It has a NW-plunging axis with the Eocene amber-bearing rocks exposed in its crest. The eastern limb of the anticline is cut off by a north-south trending fault. In the two smaller central anticlines the crests are formed by limestone of Upper Cretaceous (Cenomanian) age.

The amber-bearing deposits were described as clays by many authors, except for Chhibber (1934) who found that they consist mainly of finely bedded dark-blue shales with thin beds of sandstones of various colours (light-blue, pink, grey, 'salt-and-pepper'), and subordinate limestone and conglomerate beds. Chhibber observed that the beds had been thrown into tightly compressed anticlinal and synclinal folds, so the amber bearing hill range may be structurally more complex than Bender (1983) outlined. Chhibber believed that the limestone fragment with *Nummulites biarritzensis* collected by Stuart originated from a limestone layer in this formation. The only other fossils recorded by him are some unidentifiable plant impressions. The blue colour of the sediments changed to red or yellow in the weathered zone. The sandstones and shales contain very thin lignite seams and the amber is associated with the lignite. Chhibber stated that good quality amber is found mainly at a depth of 10–15m; the amber also occurs higher up but is of inferior quality. The amber pieces may be elliptical, oval or rounded but never irregular or angular in shape. Large blocks of amber are rare but do occur. When a particular layer of sand was reached the diggers stopped mining because they believed that there was no amber beyond it.

Chhibber (1934) lists thirteen amber sites in the Hukawng Valley, but unfortunately does not give co-ordinates for most of them. The most active site that he visited was Khanjamaw (26° 15' 50", 96° 33' 37") (Fig. 1). Other sites that he does give co-ordinates for are Ladummaw (26° 11' 19", 96° 28' 4") and Lajamaw (26° 15', 96° 28'). The Nangotaimaw site which was visited by Hannay and Noetling was deserted and Chhibber saw about 200 old pits there. Chhibber observed that the mines were 1.1m square and reached a maximum depth of 14m. The deep pits were lined by bamboo. Water often required bailing out at a depth of 12m. Digging was done with a wooden crowbar tipped with iron and the material was hauled up to the surface in baskets where it was examined for amber. Clearly this is the same technique that was observed by Hannay and Griffith nearly a hundred years before and it is likely that it had been employed for many centuries.

The main study on the physical and chemical properties of Burmite was by Helm (1892, 1893a). He noticed that it varied from yellow to brown, with a brown crust. It broke conchoidally and fluoresced blue. This latter character has been mentioned by several authors but Fraquet (1987) states that she never saw this in any specimens that she examined. It is likely that the fluorescence gradually disappears due to oxidation caused by exposure to air; a similar phenomenon was observed by one of us (V.Z.) with Sakhalin amber. Burmite is slightly harder than Baltic amber (Succinite), measuring 2.5–3 on

the Moh's scale. Several authors mention that the amber commonly has thin veins of calcite running through it; however, none of the specimens at the Natural History Museum show this feature. Burmite consists of 80.05% Carbon, 11.5% Hydrogen, 8.43% Oxygen and 0.02% Sulphur and has a specific gravity of 1.030–1.095 (Helm, 1893a).

THE AGE OF BURMITE

There is considerable confusion in the literature as to the probable age of Burmite. Noetling (1892) was the first to suggest a Lower Miocene age of the amber-bearing deposits of the Hukawng Valley. Cockerell (1917c) considered that the insect fauna in the amber was much older and could be Upper Cretaceous. Stuart (1923a) found the foraminiferan *Nummulites biarritzensis* in a limestone bed in the amber-bearing strata which was confirmed by Chhibber (1934). This led Stuart to conclude that the beds were of Eocene age, and Cockerell (1922) considered that the insect fauna in the amber was also of this age. Grimaldi *et al.* (1997) suggested it could be Paleocene or early Eocene based on its physical features. Several authors discussing the Burmite insect fauna stressed that it appears to be too archaic for the Eocene and thus may be of an older age, perhaps even Upper Cretaceous (Zherikhin, 1978; Dlussky, 1996; Rasnitsyn, 1996b; Ross, 1997, 1998). Dlussky (1996) and Rasnitsyn (1996b) considered that the Burmese amber insects could represent a relict fauna that survived into the early Tertiary. Rasnitsyn (1996a) indicates that the fauna is not tropical, which is not what would be expected.

Recent studies on the arthropods in the Burmite collection in the Department of Palaeontology of The Natural History Museum, London have revealed five insect families or subfamilies that are not known later than the Cretaceous elsewhere. They are the ant subfamily Sphecomyrminae (species described by Dlussky, 1996; although Grimaldi *et al.*, 1997 expressed doubt about its subfamilial position), the wasp subfamily Iscopinae (mentioned by Rasnitsyn, 1996b), the wasp family Serphitidae (figured in Ross, 1997), the thrip family Lophioneuridae (new species described by Zherikhin, this volume) and the whitefly subfamily Bernaeinae (new species described by Shcherbakov, this volume). These taxa are recorded from other ambers of Cretaceous age (see Poinar, 1992; Grimaldi *et al.*, 1997). Of note is that there are no extant subfamilies of ants present, which are very common in Tertiary ambers, although one ant described by Dlussky (1996), *Burmomyrma rossi*, was placed in incertae subfamiliae but may belong to the Aneuretinae. This evidence would suggest that the amber could be of Upper Cretaceous age, but this does not rule out the possibility that the fauna is relict and could still be Tertiary in age.

Clearly there is a conflict here in that the presence of *Nummulites biarritzensis* suggests a Middle Eocene (upper Lutetian–Bartonian) age for the amber-bearing deposits (see Racey, 1995), but the insects suggest an older age for the amber. This could imply that the amber has been reworked. In the literature there is some evidence to support this. Noetling found a pebble containing an ammonite which Griesbach (1892) considered was Cretaceous and came from a conglomerate within the amber-bearing sediments. More importantly, Sahni & Sastri (1957) published observations by Eames who found sub-angular fragments of a hard dark greenish-grey limestone, within a soft orange-cream foraminiferal limestone from the amber mines. He found that the hard limestone fragments contained the foraminiferan *Orbitulina birmanica* which Sahni & Sastri (1957) considered is of Cenomanian age. Clearly there were Cretaceous

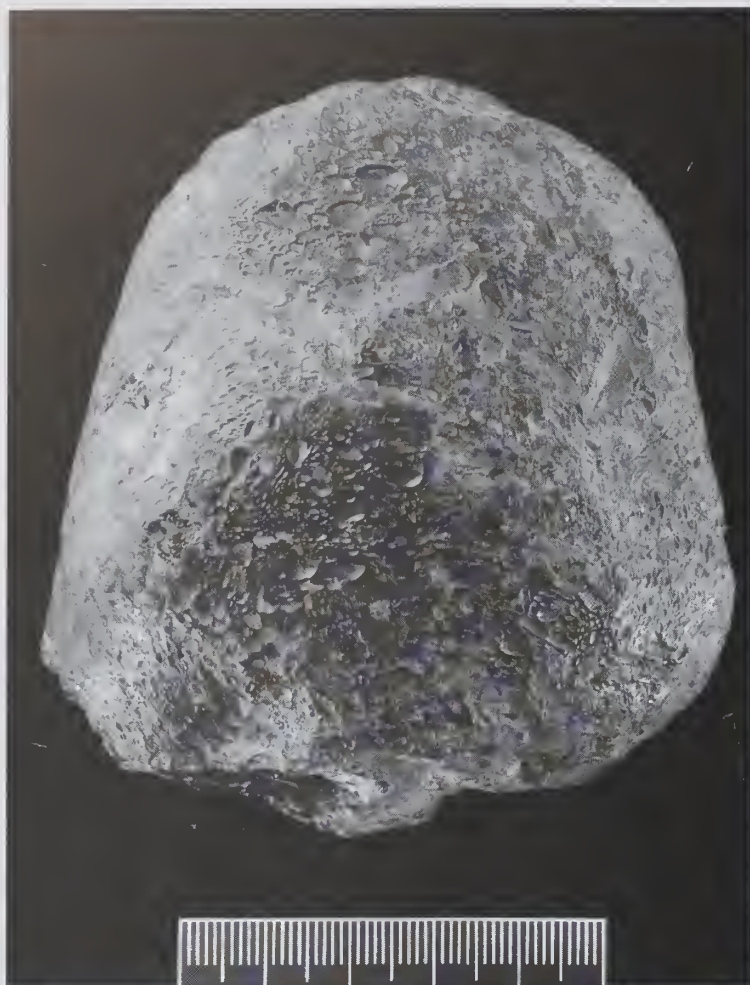


Fig. 2 Rounded pebble of Burmese amber with pits caused by impact during transportation. Department of Mineralogy, NHM 54956. Scale bar in millimetres.

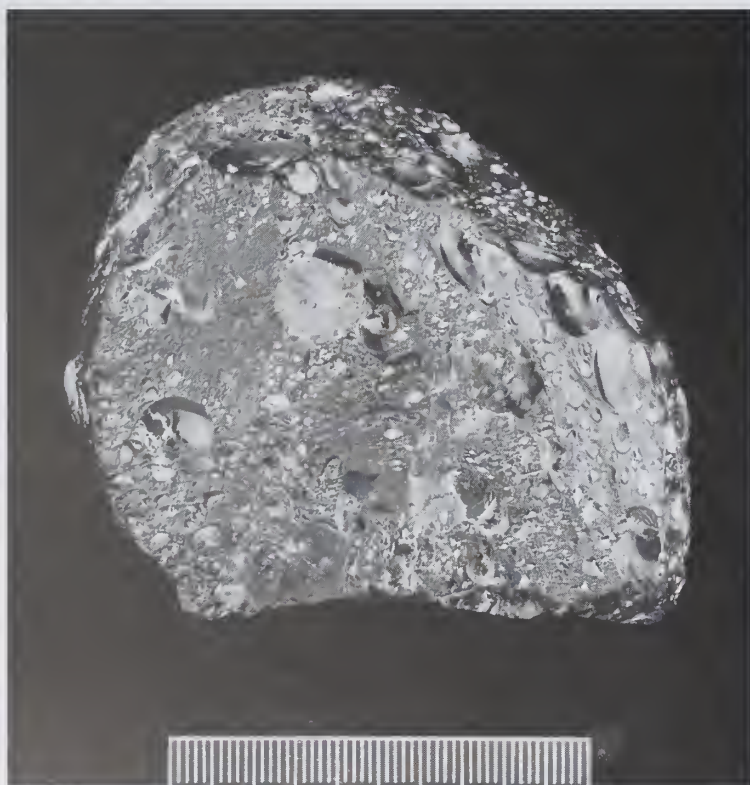
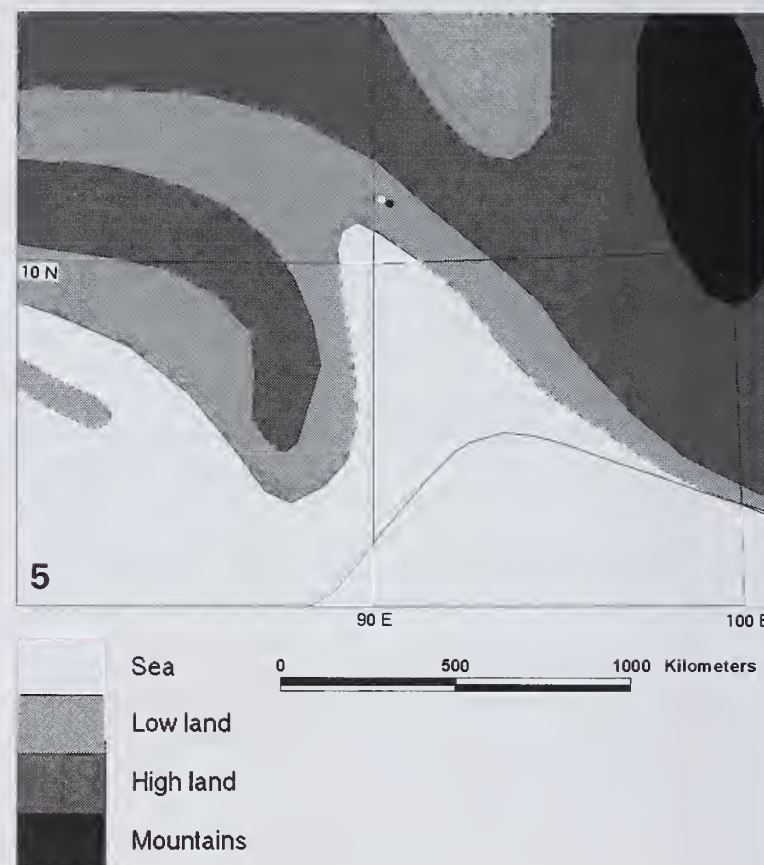
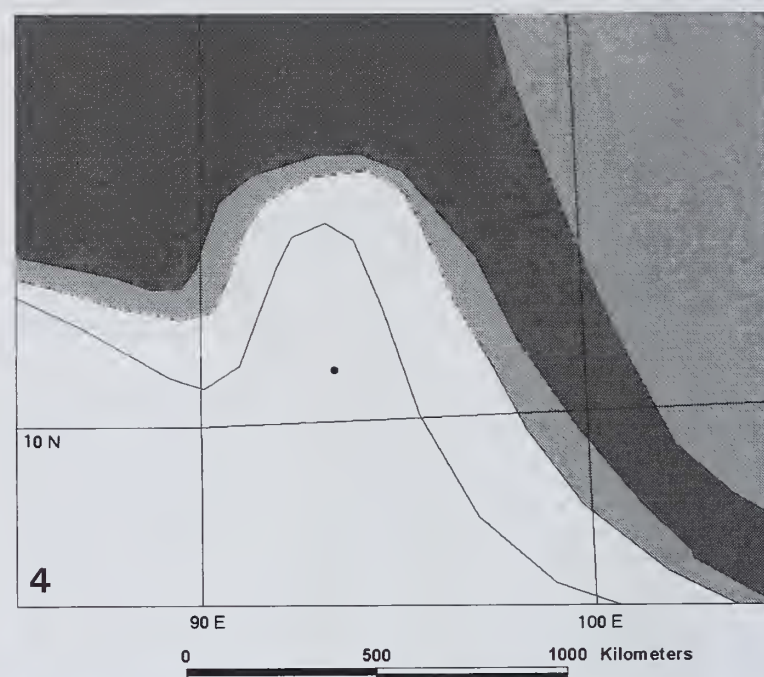


Fig. 3 Unpolished surface of a slab of insect-bearing Burmite with pits caused by impact during transportation. Department of Palaeontology, NHM In.19104-6. Scale bar in millimetres.

deposits being eroded during the Middle Eocene and clasts from them were being deposited in the amber-bearing sediments. The shape of the amber pieces themselves also suggest that they have been reworked. Both Noetling (1892, 1893a) and Chhibber (1934) observed that the amber pieces were rounded like pebbles and not angular, which would suggest that prior to deposition the amber was



Figs 4, 5 Palaeogeographic maps. **4**, for 94 Ma (Cenomanian) showing the position where *Orbitulina* limestones were being deposited (black dot); **5**, for 50 Ma (Eocene) showing the position where amber-bearing sediments were being deposited (white dot) and a possible source of derived Cenomanian *Orbitulina* limestone pebbles (black dot); in both figures the black line in the sea represents the edge of the continental shelf.

already fossilised and underwent transportation that rounded them. The large specimen in the Mineralogy Department of the NHM labelled 'Pegu' (no. 54956) (Fig. 2) is dark red, rounded and is covered by pits filled with sediment. These same pits can be seen on the unpolished surfaces of two end slabs (In.19104–6 & In.20150) (Fig. 3) cut from a large insect-bearing block of Burmite in the Department of Palaeontology (NHM). Closer examination shows that some of these pits have conchoidal fracture which develops from a single impact point at the edge of the pit. These pits support the suggestion that the amber pieces have been transported. It's possible that the 'Pegu' piece is mis-labelled and that it is Burmite from the Hukawng Valley, but further tests are required to confirm this.

Thus the available evidence suggests that Burmite is reworked and is probably of Upper Cretaceous age.

PALAEOGEOGRAPHY

From the evidence currently available there appears to be two periods of deposition related to the amber bearing deposits in the Hukawng Valley. The first was during the Cenomanian when *Orbitulina* limestones were deposited. These limestones are exposed as small inliers forming the cores of two anticlines within the Hukawng Basin (Bender, 1983). When one of the inliers, lying about 20 km south of the mines, is plotted on PaleoGIS for ArcView (Ross & Scotese, 1997–8), at 94 Ma, the map suggests these sediments were deposited in a sea (Fig. 4) at 11° N, 93° E, about 350 km from the nearest land which lay to the north-east and north-west. If Burmite was forming at this time, or later on in the U. Cretaceous, then it would have probably been produced by trees living on this land mass and could have been deposited on the continental shelf or it may even have been transported further out to sea. Later, by the Middle Eocene, these limestones were uplifted and eroded and pebbles from them were deposited within beds of limestone within the amber-bearing deposits. These younger limestones were deposited in a shallow sea as evidenced by the presence of *Nummulites*. The interbedded shales, sandstones, conglomerates and limestones suggests tectonic instability of the area resulting in repeated transgressions and regressions. When plotted on PaleoGIS for ArcView (Ross & Scotese, 1997–8), at 50 Ma (the closest age available), the map suggests these sediments were generally deposited on low-lying land (Fig. 5) at about 12° N, 90° E with higher land lying about 50 km to the north-east. The Cenomanian limestone deposit in Fig. 4 lies very close, to the south-east of this area, and could have been a direct source for derived pebbles. The primary deposits containing the amber are not known but it can be assumed that they were exposed nearby.

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